

# **Security for Enterprise Resource Planning Systems**

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## Abstract

*Enterprise Resource Planning (ERP) is the technology which provides the unified business function to the organization by integrating the core processes. ERP is experiencing the transformation which will make it highly integrated, more intelligent, more collaborative, web-enabled and even wireless. ERP systems have to be secure. Many ERP vendors are integrating security into their products. While these security solutions may work for a closed environment, we need new approaches for an open environment. This paper introduces ERP technology from its evolution through architecture to its products. The security solutions as well as directions for secure ERP systems are also presented.*

**Keywords:** Enterprise Resource Planning, Exchange Infrastructure, RBAC, Authorization, Security Policies, Web Services, SOA,

## 1. Introduction

Enterprise Resource Planning, an approach for the business integration, has been widely deployed in various kinds of organizations since it was defined by Gartner Group in the 1990s as the next generation of Manufacturing Business System and Manufacturing Resource Planning software. Today, ERP is considered to be "the price of entry for running a business" [1]. An ERP system is an integrated, configurable and tailorable information system which plans and manages all the resources and their use in the enterprise, streamlines and incorporates the business processes within and across the functional or technical boundaries in the organization. With ERP, an enterprise can automate its fundamental business applications, reduce the complexity and the cost of the collaboration, force the enterprise itself to take part in the Business Process Reengineering (BPR) to optimize its operations and finally result in the decreased operation costs and increased profits.

This objective of this paper is to give a comprehensive

discussion of the state of the art in ERP technology and the security issues for an ERP system. In particular, we discuss the evolution of ERP, the key components of ERP, the status with vendor products and also what has been done with respect to security. Our research as well as plans for secure ERP systems will also be discussed.

The organization of this paper is as follows. The history and evolution of ERP systems will be given in section 2. ERP technologies and framework including the communication platform such as EDI, ALE and Exchange Infrastructure are presented in section 3. Section 3 also includes a discussion of the ERP architecture, some aspects of SAP and the emerging web services for ERP. Major ERP vendors and their products are discussed in section 4. Security issues for ERP systems are discussed in section 5. In particular, the overview of the ERP security using a layered approach, as well as the RBAC model for ERP is discussed. We will compare these security features with the authorization function in SAP R/3 system and the Baan security solution. Some trends for ERP systems as well as security are discussed in section 6. The paper is concluded in section 7.

## 2. History of ERP Systems and Applications

The history of ERP traces back to 1960s when most organizations were developing the centralized computing systems using Inventory Control Packages (IC) in order to automate their inventory control systems. These legacy systems are mostly based on the programming languages such as COBOL and FORTRAN. Material Requirements Planning (MRP) systems were developed in 1970s in order to provide the requirements planning of products, and Manufacturing Resources Planning (MRP II) in 1980s to provide the optimization of the manufacturing processes. ERP emerges in early 1990s as an enterprise-wide and across-functional integration of the core organizational business processes

In this section we will discuss the various components of ERP systems. We will start with a discussion of the basic components in section 3.2 including Electronic Data Exchange (EDI), Application Linking and Embedding (ALE) and

web services are having a major impact on ERP systems. of applications for ERP systems. Furthermore, the emerging companies such as Oracle, SAP and Baan are developing a suite resources applications. With the advent of the web technologies, such systems were used for simple accounting and human ERP systems have evolved extensively over the years. Initially

### 3.1 Overview

## 3. ERP TECHNOLOGY

and security issues.

The next three sections will discuss ERP technologies, products quality and pedigree features are important for ERP systems. including confidentiality, privacy, trust, integrity and data underlying technologies for emerging ERP systems. Security services and service oriented architectures are the major Baan are not available in the marketplace. Furthermore, web Various commercial products including from SAP, Oracle and systems.

e-business and outsourcing applications are also relying on ERP resources management, planning and scheduling. More recently extensively for applications such as accounting, human Telecommunications. Furthermore, ERP systems are being used Transportation, Wholesale, Public Sector, and Research, Insurance, Raw and Processed Materials, Logistics, Consumer Products, Construction, Healthcare, Education and non-industrial areas: Aerospace and Defense, Banking, ERP has been utilized into the following industrial and components, ERP extends its edge into many other areas. Today, specific business domains. By providing more and more of of the modules which are more likely to be used in some In "Extended ERP" systems, the "add-ons" may include many modules of original ERP systems.

Supply Chain Management (SCM) are included into the core such as Customer Relationship Management (CRM) and considered as "Extended ERP" [2] because e-business solutions of some researchers, the ERP technology after 2000 is management, service and maintenance. From the point of view human resource management, project management, inventory, including manufacturing, distribution, accounting, financial,

Application Link Enabling (ALE) and Intermediate Document (IDoc) are SAP's proprietary technologies that help integrate the business processes within an organization; they are the basis of SAP's business framework architecture. The ALE technology contains an outbound process, an inbound process and an exception-handling process, and IDoc is the standard of the messages which flow between the functional components. Once an application document is created, an outbound process is immediately triggered and the ALE Service Layer will be requested to determine whether any other components may be interested in this information. At this time, the document will be read from the database and formatted into Master IDoc and sent to the ALE Service Layer. ALE Service Layer will generate the communication IDocs from the Master IDoc and deliver them

standard, EDIFACT, which was published in 1980s. the companies are more willing to adopt another international 1975 and ANSI ASC X.12 was published in 1979. Now most of standardization, a committee name ANSI X.12 was formed in standard form which is called EDI message. To provide this send and receive the e-documents via the network in the will usually be integrated into the system, so EDI system can read. To fulfill the tasks of translation, a third-party translator correctly transferred to the style which is able for the company recognized by the receiver and the inbound e-documents can be standardized format so that the outbound e-documents can be "translate" the documents between the internal format and the and across the enterprises. What an EDI system needs to do is to important is that EDI technology enables the integration within standardization, and better business processes. The most process including: less data errors, less processing time, less paperwork, lower cost, less inventories, less planning, technologies. It brings lots of benefits to the modern business been around for many years, is the footstone of all the ERP communication network. EDI technology, which has already computer systems, using a standard structured format over a enterprises to exchange business information between separate "paperless exchange" [3], is the technology that allows the Electronic Data Interchange (EDI), which is also called

### 3.2 EDI, ALE and IDoc

relationship to ERP systems will be discussed in section 3.4. in section 3.4. Finally emerging web services and their section 3.3. An overview of ERP architecture will be discussed exchange infrastructure that is cornerstone to ERP systems in Intermediate Document (IDoc). Next we will discuss SAP's

to the intended components. The inbound process will store the communication IDoc into the database, and a posting program will be triggered to read the IDoc and the document will be created and delivered to the application program.

### 3.3 SAP Exchange Infrastructure

With EDI and ALE technologies, distributed business processes within an enterprise have the ability to communicate with each other via one-to-one links. In a small enterprise which has a small number of components, one-to-one communication is the best way to integrate the business processes as it can be achieved with ease. But in cases where a large number of components are involved, this will bring higher complexity and cost of communication and negative impact on the stability of the environment. In this situation, a common communication infrastructure that allows the central management of the information will avoid these complications and bring more flexibility for expanding the business.

SAP Exchange Infrastructure [4] is the layer of SAP NetWeaver – SAP's integration platform for integrating heterogeneous components in a system landscape. Furthermore, with SAP Exchange Infrastructure, it is possible to create the business processes across the distributed systems which may be SAP or non-SAP systems.

The integration using SAP Exchange Infrastructure is achieved by exchanging the messages in open standards such as Extensible Markup Language (XML), and the Simple Object Access Protocol (SOAP). In the design stage, the specific integration information will be stored into the Integration Directory and Integration Repository and in the run time, they can be used for the routing and mapping. The SAP Exchange Infrastructure has the following components:

- Integration Repository that stores integration knowledge from the design time.
- Integration Directory that stores the knowledge that describes the integration-related parts of the customer landscape.
- Integration Server which contains an Integration Engine and receives the exchanged messages, determines the receiver, performs the mapping and routes the messages to the receiver system.
- Integration Monitor which monitors the exchange infrastructure.

While the SAP exchange infrastructure is the cornerstone to the ERP architecture, there are many other components to the

architecture. These components are discussed in the next section.

### 3.4 ERP Architecture

There are many disadvantages in the MRP II and MRP technologies. In an enterprise, some of the systems may be developed by the enterprise itself, while others may be developed by different vendors using different databases, languages and technologies. Systems are different from each other which makes it unable to upgrade the organization's businesses, strategy and information technologies in an effective way. With the communication infrastructure and the ERP functionalities encapsulated in components, an ERP system can easily meet these requirements. A typical ERP system should at least have the following features:

- Componentized: different business functionalities are designed as different components.
- Centralized: all the components share a centralized database management system.
- Integrated: components are integrated and seamless data flow between components allows them to collaborate as one function.
- Flexible: system is expandable and compatible with the old systems, the change to the business processes and strategies are easy to fulfill.
- Configurable & tailorable: system should be easily configured according to the enterprise's needs.
- Real-time: the components work in real time, online and batch processing modes should be available.

The business logic in ERP system employs client/server architecture to create a distributed computing environment. In the general case, the three-tier architecture will be used, which contains three layers of logic:

- Presentation Layer (Front): A unified Graphical User Interface (GUI) or browser which collects input, generates requests and returns the results back to the user.
- Application Layer (Middle): Application programs which collect the requests from the Presentation layer and process the requests based on the business rules, functions or logics.
- Database Layer (Back): RDBMS which manages the operational and business data throughout the whole enterprise and the user access to this information.

As the basis of the ERP system, an information exchange platform such as SAP NetWeaver will always be deployed

The components of an ERP system can work as separate units which can be built into other ERP systems, or they can be combined as an entire suite to implement. The enterprises can choose the most appropriate solution, purchase the components from different vendors and put them together.

- Customer Relationship Management
- Product Lifecycle Management
- Supply Chain Management
- Supplier Relationship Management (Procurement)
- Business Intelligence

These features are

ERP [2]).

The following features may be grouped by some researchers and ERP vendors into the solutions within the scope of e-commerce, yet we can also include them as part of ERP system (note: M. A. Rashid considers them as extensions of

- Financial Management which may include the functions such as collection and payment management, payables and receivables management, assets and properties management, cash management, loans, financial consolidation, general ledger, treasury management, and planning & budgeting.
- Human Resource Management which may include the functions such as payroll management, self-service, learning management, benefits, recruitment, tutor, timer and labor management, and compensation management.
- Manufacturing Management, which may include functions such as discrete manufacturing, process manufacturing, flow manufacturing, manufacturing scheduling, and shop floor management.
- Sales, Distribution and Logistics Management which may include functions such as order capture, services, sales, sales incentive management, pricing, logistics, bulk stock management, inventory management, warehouse management, requirements management, and strategic account planning.

before implementing ERP software. After consolidating the business logic and the technical platform, we will have the ERP system architecture as shown in Figure 2.

The components that different ERP vendors provide may vary, yet the core functionalities are nearly the same. These functionalities include:

#### 4. Vendors and Products

In this section we will provide an overview of the major vendors of ERP systems. SAP is one of the prominent vendors of ERP. Other vendors include Peoplesoft and Baan. However, Peoplesoft has been purchased by Oracle and Oracle is emerging has a major vendor of ERP systems. Furthermore,

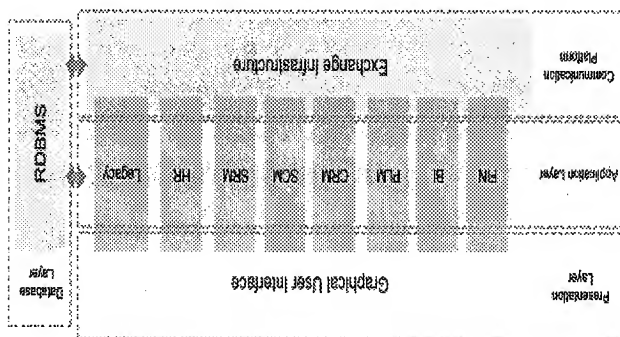
Note that the infrastructure for the web services is Service oriented Architectures (SOA). That is, web services are hosted on SOAs. SOAs provide the support to integrate and compose web services. In the emerging ERP systems, the various functions are implemented as web services and the infrastructure is based on SOAs.

The use of web services eases integration and also reduces cost. Clients want to access information without having to go thorough all the ERP software. Therefore with the use of web services and the composition of web services, clients as well as out sourcing vendors can access many of the ERP applications seamlessly. These applications include checking bank accounts, placing orders and other services. Reduction in cost comes from the fact that through web services, clients can communicate with legacy ERP software and do not have to deal with the complexities of the software. Also the ERP vendors are introducing Web Scenarios broker Hub that will act as a broker between the web services and the ERP software. SAP offers this hub through mySAP and Oracle offers it via its E-business suite.

It is stated in [9] that we are now in the third wave of ERP systems. The first wave was related to manufacturing applications. The next wave was specialized applications such as supply chain management. The third wave is based on web services.

#### 3.5 Web Services

Fig. 1 The architecture of enterprise resource planning



Oracle provides the server technologies that the ERP applications could utilize while SAP and Baan rely on various vendor products for server technologies. Note that Baan is now purchased by SSA. Microsoft is also becoming a player in ERP software. We will discuss the essential points in various products.

**SAP** (Systems, Applications and Products in Data Processing) was formed in 1972 by five former IBM employees in Germany. It focuses on the development of application software for real-time business processing with its first accounting software developed in 1973. Its first ERP product, SAP R/2, was developed in late 1970s using a centralized database and dialog control system. In 1990s, SAP R/3 which uses the three-tier architecture of database, application and user interface was unleashed on the market. R/3 was a breakthrough which made SAP become the largest vendor in the ERP market by 1999. By 2005, there were around 100,000 installations around the world, more than 1,500 partners, over 25 industry-specific business solutions, and more than 30,000 customers in over 100 countries. SAP now owns 26% of CRM market share, 29% of ERP market share and 19% of SCM market share by total software revenue. SAP NetWeaver unifies the integration technologies into a single platform which lays the foundation to integrate all the systems which runs SAP or non-SAP software. It is the basis of SAP ERP applications, partner solutions and custom-built applications. SAP R/3 is the third generation set of highly integrated software which performs the core business functions within a company; while mySAP which also includes R/3 component as an important building block will be more intended to empower the collaboration between organizations. mySAP is a web-based e-business suite.

**Oracle**, which was founded in 1970s in USA, is most famous for its well-known relational database Oracle and is the second largest software company in the world. In 1987, Oracle offered its first ERP software – Oracle General Ledger. In the following years, Oracle developed other ERP software such as self-service applications, strategic procurement solution, financial consolidation engine, and flow manufacturing product. Oracle's ERP system is known as Oracle E-business Suite which has more than 50 different modules covering the following areas: finance, accounting, human resources, manufacturing, supply chain management, project and front office. Oracle also has many other well-reputed products in other fields such as database, data warehousing, and workflow. After the acquisition

of PeopleSoft and JD Edwards in 2004, Oracle gains approximately 22% of the ERP market share. PeopleSoft Enterprise is the business application suite that offers web services integration with multi-vendor and homegrown applications; it is admittedly considered as easier to configure and more flexible than its competitors.

**JD Edwards:** JD Edwards EnterpriseOne and JD Edwards World are both the business applications from J.D. Edwards Company that has a vast experience in supplying software for the IBM iSeries platform. JD Edwards World provides the web-enabled applications for the management of plants, inventories, equipments, finances and people.

**Sage**, which was founded in England in 1981, entered the ERP market and gained a solid market share using the strategy of acquiring small ERP vendors such as Tetra, Interact Commerce Inc. By 2005, Sage has revenues of \$1.4 billion in ERP market and claims 6% of the market share as the third largest ERP vendor. Sage Line 500 v6 is the newest version of the Sage Line 500 product family which is the web-based integrated ERP solution covering core functionalities in a company. Sage 1000 is new, single business management software which is designed to offer the operations within mid-size organizations.

**Microsoft**, founded in 1975, is the biggest software company in the world with its famous Windows series products. Microsoft Business Solution Group (MBS) is the department which focuses on providing the ERP solutions, such as Microsoft Dynamics (formerly Microsoft Business Solutions) which is the integrated business management solution which includes financials, customer relationship management and supply chain management. By 2004, MBS has the revenue of around \$800 million which gives it a 4% of ERP market share.

**Others:** In addition to the above vendors there are several other ERP vendors. In 2004, the biggest ERP vendors – SAP, Oracle, Sage, Microsoft and SSA accounted for around 70% of the ERP market share by the revenues. The other 30% is shared by other ERP vendors such as Geac, Intenia, Infor Global Solutions and Lawson.

## 5. Security in ERP

### 5.1 Overview

Security is critical for ERP systems as they are being applied to numerous industries including defense, intelligence, medical and financial. First of all we need to develop a security policy

and a model for ERP systems. Many of the current systems focus on confidentiality aspects of security. In this section we will discuss the developments as well as trends in security for ERP systems.

In section 5.2, we discuss what needs to be secured. Policies are discussed in section 5.3. Then in section 5.4 we will discuss current developments including security for SAP. In section 5.5 we will discuss some of the next generation security models. In section 5.6 we will provide an overview web services security as the emerging ERP systems are based on service oriented architectures.

## 5.2 Approaches to Security

The security problems exist in every facets of an ERP system. These facets can be classified into three categories which are network layer, presentation layer and application layer which includes business processes, internal interfaces and database. When a customer/partner communicates with an ERP system, or the business components located in different sites communicate with each other, the security issues are grouped into the network security domain. ERP security research is not involved with network security. It is expected that the various network security products will ensure communication security. The presentation layer refers to the graphical user interface (GUI), browsers and PCs. Since the transmission of GUI packets is impossible to restrict, ERP security at the UI level is achieved by limiting the user access to GUI. One way to provide security to a certain extent may be just inserting a CTRIX server between the user and the ERP system.

The security in the application layer is the main focus of the ERP researchers to secure the business data and processes. The technicians will also choose to activate/deactivate the security functions provided by the database vendor according to the overall security solution. ERP research also focuses on the infrastructure security aspects such as secure web services tailored for ERP applications. Reind van de Riet has summarized in his paper (see [5]) some of the security aspects in ERP system:

- Security Policy and Administrator: ERP researchers have to specify explicit and well defined security policies that can be easily defined and maintained. The security policies will offer the rules for the access of subject to object, and these are the constraints put on the administrators when they are granting/denying permissions to the users.

Many of the current systems are based on Role-Based Access Control (RBAC). This model (Figure 3) defines roles and grants certain access rights. According to [6], an RBAC model consists of the following components:

### 5.4.1 Role-Based Access Control

## 5.4 Current Solutions

Integrity policies: These policies ensure that data is modified by authorized individuals. Furthermore, data provenance and data quality policies that determine where the data has traveled and the accuracy of the data may also be included under the integrity policies.

Trust policies: These policies ensure that data is shared only between individual organizations that are trusted.

Need to share policies: There is now a migration from need to know to need to share policies where organizations including military, financial, and healthcare agencies have to share data to carry out their operations. We discuss need to share policies in our paper on Assured Information Sharing [9].

Need to know policies: These are policies where access is granted based on whether a user needs to know. These policies are enforced in military environments.

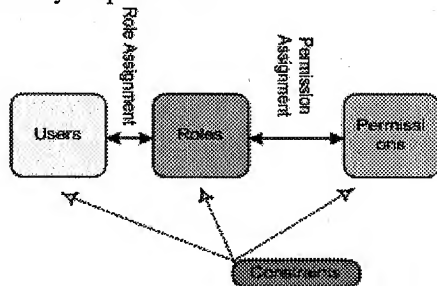
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Confidentiality is about granting access to users depending on their access permissions. However we need to include other types of policies. These include the following:

- ## 5.3 Policies
- Essentially we need end-to-end security for ERP systems. The next three subsections discuss some of the current trends and directions for secure ERP.
- User Authentication: to verify whether the user is the same person as he claims.
  - Separation of Duties: tasks must be classified such that certain tasks can only be performed by certain users or roles.
  - Authorization: to verify whether the user has the access to the relevant resources. Depending on the authorization rules, user is granted access.
  - Time Restriction: the access is permissible only during certain time.
  - Log and Trace: the logging and tracing of relevant events has to be done with preventing the log files from breach.
  - Database Security



- **Permissions:** Permission is the access to one or more objects in the system. The permission has different meanings in different environment. In a database system, the permission refers to the rights such as select, update, delete or insert a record. In an accounting application, it may be the rights such as account creation/deletion, credit/debit and transfer. [6]
- **Roles:** A role is a named job function within the organization. A role may be hierarchical. For example, an engineer role is also an employee role.
- **Users:** A user is a human being who may be assigned to one or more roles.
- **Constraints:** In the system where there is only one single administrator, the constraints may be meaningless. If the administration is decentralized, which means there are several administrators, the constraints will be used by the senior administrator to restrict the junior administrator's right to grant/deny the permissions.



**Fig.2 The model of role-based access control**

### 5.4.2 Authorization in SAP R/3

Some of the concepts involved in the authorization in SAP R/3 system are listed below [7]:

- **Authorization Object**, which represents the authorization concept and consists of some authorization fields.
- **Authorization**, which is an instance of one authorization object and defines the permitted value range of each authorization field of the authorization object.
- **Authorization Profile**, which contains some authorizations which are assigned to the user by the administrator.
- **Authorization Check**, which is used to protect the transactions or data you choose, and is embedded in the program logic. When the authorization check is performed, the authorization profile will be used to compare with the required values to run the specific transaction.
- **User Master Record**, which enables the users to log into the R/3 system and grant limited access to the transactions and data.

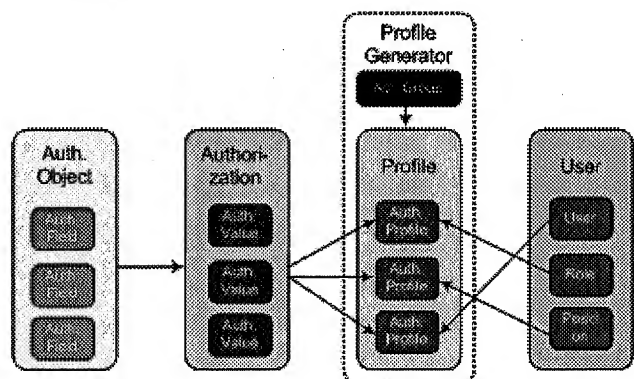
- **Profile Generator**, is the component that helps the administrators create, generate and assign authorization profiles using activity groups and user.

A profile generator may have the following components:

- **Activity Group** is a collection of activities such as tasks, reports and transactions. An activity group usually represents a job in the enterprise. An activity group can have many users assigned to it, and a user can also be assigned to many activity groups. An activity group can be assigned to the following types of users: user ID, job and position. Job represents the general classification of duties. Position represents a person's detailed individual assignment within an enterprise. The difference between job and position is that job is just the title which does not imply what projects you will do in the company, while position does so.
- **Composite Activity Group** is the collection of several activity groups.
- **User Assignment** is the task that assigns one or more users/roles/positions to one or more activity groups or composite activity groups.

Another important concept in the authorization in R/3 is Authorization Administration which means whether the creation, generation or assignment of authorization is centralized or decentralized (one or more administrators).

Through these concepts, we may learn that the mechanism of R/3 authorization is actually an instance of Role-Based Access Control Model, except that it contains some elements specifically used in R/3 environment. Figure 4 provides a visual understanding of the model of authorization in R/3 system. Furthermore, Logging and Tracing is also a required component to secure the application layer of ERP system, although it is not the key function.



**Fig. 3 The model of authorization in r/3**

### 5.4.3 Baan Security using DEM

In Baan (now purchased by SSA) security architecture, the solution is based on the RBAC model. Baan security solution is using a tool named Dynamic Enterprise Modeler (DEM) to assist the security configuration of Baan. DEM is used to model business processes or functions of an organization and defines the roles. Within the architecture of Baan's security solution, there are four concepts: User, Employee, Role and Process.

- User: Baan user is a profile including all the personal information of an employee.
- Employee: The human being who works in the organization.
- Role: Role is defined to indicate the position and the assignments of the employee. All employees must be assigned to a role, and roles will be assigned to the business processes.
- Process: Once a process is modeled in Baan ERP, roles will be attached to that process.

### 5.5 Next Generation Models

#### 5.5.1 Extended RBAC

Most of the contemporary ERP software adopts traditional access control methods such as RBAC as its primary measure to secure the system. What these methods care is whether some subject is allowed to perform the requested rights on the object. In some cases, the subject has to meet some mandatory requirements before exercising the rights. A good example is that the researcher has to fill in his/her personal information before he can have the rights to read or download the white papers. This mandatory requirement is Obligation [8]. Another important requirement for accessing the resources is the environmental or system requirement which is called Condition [8] such as accessing time, date and location. Since these functional predicates are not included into the idea of traditional access control methods, a straightforward enhancement of RBAC is to introduce obligation and condition predicates.

In this ERBAC model, an extra decision manager is added since obligation and condition predicates will be taken into account. In the decision process, condition requirements will be checked first; if all the environmental conditions are met, the checking procedure for the obligations will be triggered; and the decision process will check whether the user is intended to access the information. Srinivasan and Thiraisingham are examining the extended RBAC model for ERP [15].

### 5.5.2 UCON

In recent years, a new model called the Usage Control Model (UCON) was proposed in order to set up a framework for the future security techniques in ERP. UCON not only integrates three functional predicates: authorization, obligation and condition, but also brings in the concept of time. This feature allows a security component in ERP system to be far more dynamic than before [8].

- Subject and subject attributes: An entity with associated attributes which holds or exercises certain rights on objects.
- Object and object attributes: An entity with associated attributes that one or more subjects hold or exercise rights on.
- Rights: Privileges that a subject can or cannot access an object.
- Authorization: Functional predicate determining whether a subject is allowed to perform some right on an object.
- Obligation: Functional predicate verifying whether the mandatory requirements have been fulfilled before a subject performs some right on an object.
- Condition: Functional predicate that checks whether the current environmental or system status allows a subject to perform some right on an object.

UCON model is a large model family in which one can have different combinations of the above three predicates. If we regard the UCON model with only one of these predicates used as the leaf node, we can build up a tree rooted at UCON<sub>ABC</sub> model. These models are denoted UCON<sub>A</sub>, UCON<sub>B</sub>, and UCON<sub>C</sub>. These models will be divided into several sub models based on whether time is taken into consideration. For example, UCON<sub>A</sub> will be divided into UCON<sub>A<sup>prev</sup></sub> and UCON<sub>A<sup>onA</sup></sub>. Furthermore, these sub models can be divided into more detailed models depending on when and whether the update of mutable attributes will occur. We are currently investigating the applicability of UCON features for ERP security.

### 5.6 Web Services Security

As we have mentioned earlier, web services and service oriented architectures (SOA) are key technology for emerging ERP systems. Vendors such as SAP and Oracle are migrating their products based on three-tier architectures to web-based SOAs. Therefore, securing web services and service oriented architectures are critical for securing emerging ERP systems.

Various efforts have been reported on securing web services [10]. Furthermore, standards such as OASIS have developed security specifications including SAML (Security Assertion Markup Language) and XACML (XML Access Control Markup Language) [11]. In addition securing XML documents as well as securing semantic web technologies has received attention [12], [13]. Programs such as the Department of Defense Global Information Grid (GIG) have focused on security for service oriented architectures [14]. However little work has been reported on adapting the various technologies for securing ERP. This will be the major challenge.

## 6. Trends

Looking back at the history of ERP technology, we can find that the transformation from mainframe structure into the client/server architecture has been a major step. With this architecture, it became possible to develop a large system which integrates lots of functionalities. Today, ERP has become the core of the operation and business in a company. With the emergence of the web, ERP systems will be web-based. We can expect the future of ERP system to include the following features:

- **Heterogeneity:** Heterogeneous/heterogeneity means that the components from different vendors coexist and cooperate in an ERP system. It has two prerequisites: componentization and integration. It is true that some of the leading ERP vendors are going to or have already done something in these two aspects. Stronger communication platforms are provided to support heterogeneous applications and applications are developed in the form of components.
- **Collaborative:** This could be in the realm of e-business. We can classify the business processes within an enterprise into two types: enterprise-centric process and collaborative process. Processes such as accounting and payroll processing are enterprise-centric; while others such as supply chain management are almost completely collaborative. There are some intervenient processes, yet they are designed and developed in an enterprise-centric way. In the future, more of the processes will be redesigned in a collaborative way. This feature also implies that the ERP system will be more open and web-based.
- **Intelligent:** ERP system will include more components which carry out analysis, investigation or even advice on strategic transformation. This feature implies that more confidential information will flow within or out of an ERP system.

- **Web-based:** With the emergence of the web, it is natural that the functionalities or services will become web-based, which will make the system highly vulnerable to the security threats.
- **SOAs and Web Services:** As we have stressed in this paper, future ERP systems will be based on SOAs. Such architectures provide the infrastructure to integrate and compose multiple web services.
- **Wireless:** Access to the ERP system from a mobile device.

Currently, to secure an ERP system, there are two methods: access control and logging. However there are factors that may prevent corporations from incorporating security into their ERP system. One reason is due to the cost and time. Furthermore, stringent security controls make the operation more complex and difficult to use. In a large enterprise, there will be many activities that may change an employee's authorization level, such as promotion or reassignment. This will make the user-based access control difficult to implement. Logging systems that involve the logging of detailed activities are costly and may have low performance as they have to trace every event and log all activities. As ERP systems become web-based, the security issues within an open system become critical.

Usually, the better security solutions will result in higher cost and lower performance. This contradiction exists in any system. However, ERP subsystems are used to lower the cost and increase the profit of an enterprise; hence the performance of the system will be considered as most important by the executives of an enterprise. While there are important factors that may deter security, security is crucial to protect the data and the processes. Therefore we need flexible security policy management and enforcement. There are times when security has to be overlooked to achieve performance, especially for real-time applications. However, in such situations, the implications of violating security have to be studied at length and appropriate actions have to be taken.

## 7. Conclusion

This paper has provided an overview of ERP system as well as security for ERP systems. ERP is the technology which drives the reformation in the realm of economy and impacts people's life styles indirectly. In the ensuing years, we expect ERP systems and applications to be more integrated and intelligent. Furthermore, such systems will be web-based, service oriented and even wireless. The security issues for ERP systems have been present for a while, but due to the closed environment with current ERP systems, not much research has been carried out in

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- ERP systems.
- SOAs we are providing a comprehensive solution for securing examining security for supply chain management as well as These web services are integrated using SOAs. Therefore, by various functions of an ERP will be executed as web services. The infrastructures such as secure SOAs and web services. The integral part of ERP system. The other is securing the applications such as supply chain management which is an Our research is proceeding in two directions. One is securing technology for secure ERP systems.
- secure service oriented architectures are emerging as a major of a secure ERP system. In addition, web services security and Essentially research should focus on a policy, model and design components (e.g. operating system, database systems, Logging We also need to examine the interfaces between the different components (e.g. operating system, database systems, Logging component etc.) and ensure that the interfaces are secure. of a secure ERP system. In addition, web services security and secure service oriented architectures are emerging as a major technology for secure ERP systems.
- Our research is proceeding in two directions. One is securing applications such as supply chain management which is an integral part of ERP system. The other is securing the various functions of an ERP will be executed as web services. These web services are integrated using SOAs. Therefore, by examining security for supply chain management as well as SOAs we are providing a comprehensive solution for securing ERP systems.
- Securing the transferred data
  - Developing user authorization methods
  - Enhancing the logging mechanism
  - Securing the database
  - Securing the operating system
  - Securing web services
- including the following:
- ERP system. The research should focus on several aspects carried out. In particular, we need end-to-end security for an ERP security must be emphasized and much research has to be security. However, with the open environments of the future,
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